SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

Be it known that I, Robert J. LeJeune, a citizen of the United States of America and a resident of Lafayette, Louisiana, have invented a new and useful autonomous apparatus and method for acquiring borehole deviation data of which the following is a specification.

APPLICATION FOR PATENT

INVENTOR: Robert J. LeJeune

INVENTION: An autonomous apparatus and method for acquiring borehole deviation data

SPECIFICATION

1. FIELD OF THE INVENTION

This invention relates generally to apparatus and methodology used to determine the deviations from the prescribed path of a borehole and more particularly to a low voltage autonomous instrument package used to acquire deviation angle data down hole and a method for retrieving and correlating the data upon the instrument's return to the surface.

2. GENERAL BACKGROUND

During the process of drilling an oil or gas exploratory or development well borehole, it is necessary to determine where the drill bit is located at all times and the bit's deviation from the prescribed path. Depending on the type of well, such as vertical or directional bore, it is imperative that down hole measurements such as direction and deviation angle relative to a vertical axis be measured accurately and frequently.

Mechanical autonomous devices presently used to measure deviation angle "only", include pendulum pin prick mechanisms coupled to a mechanical timer housed in a relatively slender tube commonly referred to as one shot deviation recorders. The

mechanical timer is set at the surface of the well bore prior to dropping the tube down the central bore of the drill string. The mechanical timer is manually set to a predetermined time for activation of the pendulum pin prick mechanism at approximately the same time the slender tube containing the timer and the pendulum pin prick mechanism reaches the bottom of the borehole. The pendulum pin prick mechanism, when activated by the mechanical timer, causes a pin prick hole to be formed in a paper target at an angle congruent with the angle the pendulum pin prick mechanism is deviated from vertical. The paper target has concentric rings representing degrees of deviation, printed on the surface exposed to the pendulum pinprick mechanism. The slender tube containing a pendulum pinprick mechanism and a mechanical timer is either retrieved by wire line or "tripped" out of the borehole with the drill pipe. The paper target is then retrieved from the pendulum housing and inspected. The deviation angle in degrees is then estimated by determining the location of the pinprick hole formed by the pendulum pinprick mechanism and the nearest printed concentric circle on the paper target.

The pendulum pin prick mechanism and a mechanical timer method of retrieving borehole measurements is an industry standard that is the most commonly used method of inexpensive and "quick check" of borehole measurements. However, the use of this method requires that all drilling activities cease and creates a downtime situation that leaves the drilling operators exposed to problems such as "stuck pipe", lost circulation, or "blowout', occurring in open hole conditions. The potential always exists of a premature timer activation or non-activation, and, since this is a "one shot only" method, such failure would require the method be repeated resulting in additional downtime costs. Other problems exist with the pendulum pinprick mechanism and its mechanical timer

method including limited angle range of the instrument and the fact that the resulting paper target is simply an estimate and thus open to interpretation.

Other methods employed by the oil and gas industry to measure borehole parameters is the gyroscopic deviation angle or "Gyro Multi-shot Deviation Angle ". The Gyro Multi-shot instrument consist of a magnetic compass and tilt indicator mounted above a spinning gyroscope. A camera with a timed shutter release is mounted so that multiple pictures can be taken of the magnetic compass reading and the tilt indicator. The operator at the surface then attaches the Gyro Multi-shot instrument to a "wire line" and lowers it into the borehole. The Gyro Multi-shot instrument is stopped at the desired depth where the timed shutter release is activated and a picture of the compass reading and tilt indicator is taken. The process is repeated until desired deviation angles are completed and the Gyro Multi-shot instrument is retrieved. The camera film is then retrieved, developed and analyzed. Although the Gyro Multi-shot instrument is accurate and reliable, development of the camera film and analysis of the deviation angles can take considerable additional time and is also vulnerable to the same problems of the "pendulum pin prick" mechanism method. In addition, the multi-shot method requires trained operators, thereby incurring additional cost.

3. SUMMARY OF THE INVENTION

Accordingly the instant invention addresses the shortcomings of the prior art by providing an improved method and system for autonomously gathering borehole measurement data. The improved system utilizes a low voltage, solid state electronic apparatus and a method for detecting and correlating desired measurements such as pitch,

roll, azimuth and temperature taken from a bored hole in an autonomous manner, and recovering such data from the instrument upon its return to the surface. The apparatus itself utilizes electronic measurement sensing circuitry that includes a compass/magnetometer utilizing a tilt compensated linear compass, dual axis tilt system, an integrated circuit board having a low voltage programmable micro-controller unit that includes a micro-storage device, a micro-timing device, an onboard high temperature power supply unit including power regulating electronic circuit, and a capacitor circuit all housed in a high tensile strength non-metallic casing sleeve with a self centering capability. The system further includes electronic communications programming and retrieval cabling and a portable computer processor unit.

There is also disclosed a method for inputting data into and retrieving data from the borehole instrument. The method of operation includes the steps of providing the autonomous instrument with a an onboard computer program capable of establishing a start time delay, a timed interval for acquiring a plurality of desired duplicate measurements taken from the borehole, providing a time input method for inserting a time mark associated and identifiable with each of the data measurements taken autonomously down hole, and providing a method for storing a plurality of such measurements taken along the borehole path with their associated time marks in memory. The method includes a second computer program utilizing a computer-processing unit to process and display the desired measurements taken along the borehole retrieved from the autonomous instrument upon its recovery at the surface of the borehole. The computer processing system is capable of averaging the desired measurements taken at any given point along the borehole and displayed according to the actual depth at which the desired

measurements occurred.

4. BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the nature and objects of the present invention, reference should be made to the following detailed description taken in conjunction with the accompanying drawings, in which, like parts are given like reference numerals, and wherein:

FIG. 1 is a cross section view of a well bore utilizing the deviation angle instrument package assembly;

FIG. 2 is a cross sectional cut-a-way view of the deviation angle instrument package assembly and running gear located adjacent the drill bit;

FIG. 3 is a side elevation view of the deviation angle instrument package;

FIG. 4 is a side elevation view of the deviation angle instrument package and running gear with centralizer collapsed;

FIG. 5 is a side elevation view of the deviation angle instrument package and running gear with centralizer expanded;

FIG. 5A is a partial cross section view of the centralizer retracted;

FIG. 5B is a partial cross section view of the centralizer extended;

FIG. 6A is a partial cross section view of the deviation angle instrument package assembly;

FIG. 6B is a partial cross section view of the deviation angle instrument package assembly;

FIG. 6C is a partial cross section view of the deviation angle instrument package assembly;

FIG. 7 is a block diagram of the components of the deviation angle instrument package;

FIG. 8 is an isometric view of the input/output computer terminal and connection; and

FIG. 9 is a process diagram.

5. DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

As seen in **Fig. 1**, unlike most other well deviation angle instruments, the instant deviation angle instrument package assembly **10** may be operated completely autonomously with no communication with the surface of the well **12**. The instrument package assembly **10** is simply preprogrammed and dropped into the bore of the drill string **14** and allowed sufficient time to reach the bottom of the well bore via the drill string internal bore to a point adjacent the drill bit **16**. As shown in **Fig. 2**, the deviation angle instrument package assembly **10** is conveyed through the longitudinal bore of the drill string **14** by conventional running gear including upper connector member **18** and lower shock absorber connection member **20**. The running gear component members **18,20** help cushion the instrument package assembly **10** and provide a means for retrieval if necessary. The running gear **18** and **20** also includes an expandable centralizer **21** shown in detail in **Figs. 5A** and **5B** and shown compressed in **Fig. 4** and expanded upon impact with the bottom of the drill string in **Fig. 5**, thereby insuring that the instrument is maintained in a stable representative position of the true angular deviation of the drill string **14**.

A unique centralizer **21** used for impact deployment is detailed in **Figs. 5A** and **5B** and includes a tubular body member **23** with internal detent ridges **25**, an elongated tubular member **27** with a solid portion **31** at one end and a detent means **41** located at the opposite end of the body **27** being telescopically slidable within the tubular body member **23**, a swivel spear head **45** adapted for coupling with retrieval tools attached to the solid portion

31, and a flexible stabilizer band **47** located externally of and intermediate to said solid portion **31** of the tubular member **27** and the tubular body **25**.

The deviation angle instrument package assembly **10** seen in **Fig. 3** is a non-metallic casing sleeve divided into three parts: the upper power supply housing **22** capable of connection to the upper running gear component **18** via male tandem sub and cap assembly **23**, the communication sub housing **24** including its input/output port **26** and the lower housing **28** containing the electronic instrument components of the instrument, capable of connection to the lower shock absorber component **20** of the running gear via the female tandem sub **29**.

Looking now at a cross section of the instrument package assembly **10** in **Fig. 6A** we see that the power supply housing **22** includes power supply in the form of a battery pack **30** arranged so that the battery pack's negative power terminal **32** is in contact with the negative terminal **34** biased by a spring **36** in contact with the metal cap **23**. The positive end **38** of the battery pack is in contact with the positive system terminal node **40**. The battery power pack may be between 7 and 25 volts and should be a capable of withstanding high heat and pressure such as a Lithium Bromide Cell. The voltage output to the compass and stamp computer is voltage compensated to 5 volts and a maximum of 52 milliamps. Wiring communication from the battery power supply **30** to the communications port **26**, as seen in **Fig. 3**, is made via a central bore **42** located in the communication sub **24** and beyond to the lower housing **28** seen in **Fig. 6B** containing the electronic instrument components of the instrument. The instrument's electronic survey components **43**, as seen in **Fig. 6B**, located in the lower housing seen in **Fig. 6C**, include a microprocessor **44**, a micro data storage or memory card **46**, a clock **48**, and the angle/

direction sensor **50**. The angle/direction sensor unit **50** also includes a solid state, tilt compensated compass engine **51**, a solid state, dual axis tilt or pitch engine **53**, and a temperature monitor **55** as diagrammed in **Fig. 7**. The sensor unit **50** is capable of out-putting a continuous heading, magnetic field, and dual axis tilt and temperature data over a wide range of interfaces. Azimuth is generated from its 3-axis semiconductor magnetometer. Linear tilt is provided with 12-bit resolution over +/- 80 arc/deg. Resolution. The electronic survey components **43** are specifically designed in a vertical or linear circuit board configuration for this application.

In use, as diagrammed in **Fig. 9**, the first step **70** is to enter the desired well survey parameters, such as times and intervals, into the computer **58** seen in **Fig. 8**.

Since the instrument package assembly **10** is autonomous, it must be preprogrammed with the particular well parameters before being deposited within the drill string as seen in **Fig. 8**.

The next step **72** is to program the instrument package assembly **10** by temporarily attaching the surface computer **58** to the communications port **26** with communications cable **66** as shown in **Fig. 8**, at which time the delay times and survey interval times are entered into the memory portion of the onboard microprocessor **44**, seen in **Figs. 6B, 7**, portion of the instrument survey package. Delay times are calculated based on the time computed for the instrument to freefall to the bottom of the well, generally about 1000 feet per minute, plus the anticipated time for insertion into the running gear **18,20** and deposition into the drill stem **14**. Interval times are generally set for 3-5 minute intervals but depend generally on the operational time required to withdraw the drill stem sections. After installing the instrument package assembly **10**

into the running gear **18,20** and inserting the running gear into the drill pipe or string, steps **74** and **76**, the running gear **18, 20** is allowed to free fall to the bottom of the well. The impact of the running gear hitting bottom deploys **78** the centralizer assembly **21**. After the "delay time" has expired **78**, the micro controller **44** initiates a series of interrogations. The down hole micro controller **44** interrogates the clock **48** for a time stamp, the compass engine **51** for direction, angle, temperature, pitch and roll. Returns from these sensor readings are then sent to the micro data storage **46** for storage. This series of interrogations is completed four (4) times and stored in the micro data storage as the RAW file. The micro controller then "sleeps" until the next preprogrammed "survey interval" has expired.

During the next survey interval and while the micro controller "sleeps", the instrument package assembly **10** is being lifted to the next survey depth by removing or "tripping" the drill pipe **80**, or while retrieving the instrument package assembly **10** and running gear assembly **18,20** by "wire-line". In either case, the interrogation process is repeated until the instrument reaches the surface and the instrument package assembly **10** is removed from the "self centralizing running gear" and the RAW data is downloaded to a Proprietary Visual Basic Laptop computer program **58**.

The surface survey operator simultaneously enters the time of withdrawal of each section and the calculated depth of the instrument at that time **84**. When the last remaining section of drill stem reaches the surface of the well, the instrument package assembly **10** is retrieved. The surface computer **58** is again connected to the instrument's communication port **26** and the stored survey data is uploaded to the surface computer **88**.

The RAW survey data file is uploaded directly from data storage **46** via microprocessor **44** upon command from the surface computer **58**. The RAW survey data file is provided in the following format:

RAW Data File

Time	Direction	Angle	Temp	Pitch	Roll
T:00:00:01	**D:353.614**	**A:25.071**	**t:3.3**	**P:22.06**	**R:11.79**
T:00:00:06	**D:353.675**	**A:25.079**	**t:3.4**	**P:22.19**	**R:11.79**
T:00:00:11	**D:353.614**	**A:25.106**	**t:3.4**	**P:22.25**	**R:11.69**
T:00:00:16	**D:353.526**	**A:25.068**	**t:3.4**	**P:22.10**	**R:11.75**

Notes:
T: time (time stamp for survey from clock on main board)
D: direction (magnetic direction reading from compass engine)
A: Angle (tilt angle computed by compass engine)
t: Temperature (internal temperature of the compass engine).
(Not used in any computations)
P: Pitch (pitch angle from compass engine)
R: Roll (roll angle from compass engine)

A depth file is generated by the surface computer **58** based on a time stamp derived from its internal clock wherein the depth is entered manually by the surface operator and a finish time is derived from the difference between the time stamp and the actual manual input by the operator. The depth file is provided in the following format:

DEPTH FILE

Time stamp	Depth	Finish
T:10:48:14,	**10,000,**	**10:48:21**
T:10:51:07,	**9,000,**	**10:51:09**
T:10:54:00,	**8,000,**	**10:54:17**
T:10:56:52,	**7,000,**	**10:56:56**

Upon initiation of the survey process, the surface recording unit (laptop computer) **58** using the proprietary visual basic laptop program begins a series of depth interrogations. Using the same "survey interval" timing set in the micro controller **44**, instrument package assembly **10**, down hole, the surface recording unit (laptop) **58** will request a depth input from the operator at precisely the same time the micro controller **44** is interrogating the down hole clock 48 in the instrument package assembly **10**. The operator then ascertains the survey depth by calculating the actual bit depth less the actual location of the instrument package assembly **10** within the drill string **14**. The surface operator manually inputs into the laptop computer **58** the actual survey depth, which is then recorded and stored in the laptop memory in the "Depth File".

Should the operator decide for any reason that the survey taken at the interrogated depth is not valid, (i.e. pipe was moving, survey not valid); the operator can input "**0**" for "null" depth. If at any time, the depth input time and finish time exceeds **30** seconds, the proprietary visual basic laptop program **58** will initiate a "null" depth entry for that survey, and continue the timing sequence uninterrupted.

A "**G**" or gravitational file is generated as derived from the time stamp taken from the down hole clock 48 at each interval utilizing an average direction and tilt angle referenced with average temperature. The "**G**" file is a mathematical average of the four (**4**) survey samples to arrive at one averaged survey data sample. Note: As the tilt or deviation angle approaches zero, direction becomes vague or nonexistent. The compass engine therefore cannot distinguish direction below **1** degree and can cause degradation of all measurements. The compass engine manufactures installed a one-degree filter to

eliminate possible discrepancies. It is important to the potential users of this instrument to read deviation angle below **one** degree. The "G" file therefore calculates an alternative tilt angle derived from the formula :

$\sqrt{\sqrt{P} + \sqrt{R}} = D$, The square root of the square root of the pitch plus the square root of the roll equals the deviation angle.

This file is generated in the following format:

G FILE

Time	Pitch	Roll	Deviation
T:00:00:16,	353.60725 ,	22.2194177466467,	3.375
T:00:03:21,	353.58975 ,	22.2148289437484,	3.4
T:00:06:25,	353.59325 ,	22.2575915419885,	3.4
T:00:09:30,	353.581 ,	22.2473661362418,	3.4

A "**C**" or compiled file is generated by integrating the "G" file data and the "D" depth files to arrive at one sample survey for each time stamp and a depth for each sample. (null samples are disregarded). The file consist of:

C: Compiled File

Time	Avg. pitch	Avg. roll	DEV. Angle	Time stamp	Depth	Finish time
T:00:00:16,	353.60725,	22.219,	3.375	!!!10:48:14,	10000,	10:48:21
T:00:03:21,	353.58975,	22.214,	3.4	!!!10:51:07,	9000,	10:51:09
T:00:06:25,	353.59325,	22.257,	3.4	!!!10:54:00,	8000,	10:54:17
T:00:09:30,	353.581,	22.247	3.4	!!!10:56:52,	7000,	10:56:56

Notes: T: time stamp from down hole clock, direction (averaged), tilt angle (averaged), internal temperature (averaged), !!! Time stamp (from laptop), Depth (manual input from laptop), Finish time (from laptop)

A "P" or process file is produced that combines the pertinent well information with the data from the compiled file in rich text format for import into a spreadsheet format. This file is produced in the following format and consists of:

P- FILE

Measured Depth	Drift Angle	Drift Direction
10,000,	**22.219,**	**N,6.38,W**
9,000,	**22.215,**	**N,6.41,W**
8,000,	**22.258,**	**N,6.41,W**
7,000,	**22.247,**	**N,6.42,W**

Notes: Measured Depth, Drift angle (tilt angle), Direction, (converted to quadrant from degrees)

SPREADSHEET

A spreadsheet is produced consisting of two pages; page two is a gathering point indicating that the processed file is received. Page one of the spreadsheet is the finished product and printable hard copy of the imported data and the calculations derived from the survey data.

Using industry standard calculations, and other manual inputs, the spreadsheet can calculate sub sea depth, true vertical depth, vertical section, North/South variance, East/West variance, dogleg severity, and closure distance and direction.

With this instrument, very precise and reasonably accurate well bore deviation angles can be recorded while tripping resulting in considerable savings due to significant down time required when using a wire-line.

Because many varying and different embodiments may be made within the scope of the inventive concept herein taught, and because many modifications may be made in the

embodiments herein detailed in accordance with the descriptive requirement of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in any limiting sense.